Coastal Engineering Technical Note

NUMERICAL MODEL FOR RUNUP AND OVERTOPPING ON RIPRAP REVETMENTS

Program Purpose: RBREAK2 is an advanced numerical model for calculating runup and overtopping on rough slopes of arbitrary geometry.

General: Assessing the runup and overtopping potential of proposed or existing revetments is essential to design of the revetment or design of drainage systems behind the structure, or assessing flood and damage potential critical to an economic evaluation of the structure. Typically, runup and overtopping estimates are made based on physical models or empirical equations, either of which has limitations. Common prototype conditions such as compound slopes, offshore bars, or varying bottom roughness are particularly difficult for estimating runup and overtopping.

An advanced numerical model for calculating runup and overtopping on rough slopes of arbitrary geometry has been developed at the University of Delaware, then modified into a more user-friendly program under a contract with the USAE Waterways Experiment Station's Coastal Engineering Research Center (CERC). The model, RBREAK2, reproduces spectral wave action across a structure and calculates water surface elevations at each spatial node throughout the time-stepping routine. Runup is determined as the maximum distance up a revetment where the water surface elevation is at least a specified distance above the slope. The program is capable of estimating overtopping if the slope is of insufficient length to determine maximum runup, and calculating transmission past submerged structures.

Use of the numerical model described herein should aid preliminary design studies, reducing required physical model testing, analysis of existing structures, and estimation of flooding potential over structures. Use of the program requires writing a primary data input file and calculating the friction coefficient, both of which are described in this CETN. The numerical model may be used to analyze a wide variety of possible configurations or options, but it should be emphasized that results are only estimates and cannot replace physical model testing for accurate analysis of the final design selected for a project.

Limitations: 1) The program does not compute flow through a porous armor layer, but calculates energy losses by use of a friction factor based on the roughness of the slope. A means of calculating the friction factor is presented in this CETN. 2) The program is a one-dimensional model and is limited to normally incident wave trains. A two-dimensional model is being developed at the University of Delaware and should be available at CERC in late 1994. 3) The program exceeds the 640-kilobyte limitation imposed by DOS and is therefore not available for DOS-based personal computers. The program is currently running at CERC on a VAX 3600, an HP 9000 workstation, and a Cray Y-MP supercomputer.

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Overview: Detailed information on the mathematics and numerical methods employed in RBREAK2 are described in the user manual for the program (Kobayashi and Poff 1994[1]). This paper will therefore present only a brief overview of the model and required input data.

RBREAK2 uses a numerical flow model to predict flow characteristics on a rough impermeable slope of arbitrary geometry and was developed such that any monochromatic, spectral, or user-defined normally incident wave train could be specified at the toe of the slope. The model is based on conservation of mass and momentum in finite-amplitude shallow-water equations in Madsen and White (1976)[2] which include the effects of bottom friction. A discretized finite difference grid of constant space and constant time-step is solved by an explicit dissipative Lax-Wendroff method.

RBREAK2 does not compute energy dissipation through porous media, but rather calculates energy losses by a friction coefficient which is based on roughness of the slope. Determination of the friction coefficient for a particular slope under a given incident wave set is described below; calibration of the model is required for cases in which the friction coefficient has not been determined. Calibration of the program may be done with data from laboratory studies given the dimensions and type of armor units, structure slope geometry, and incident wave conditions.

Computed oscillations of the waterline on the slope are used to predict runup and rundown, which are determined at a specified vertical distance above the slope. This measurement is related to the use of a waterline meter that has a given height above the slope. While it is possible to enter several different heights for the calculations, results indicate that wave runup is relatively insensitive to this height. Wave rundown, however, is very sensitive since a thin layer of water remains on the slope during downrush.

Reflected wave train is computed from wave characteristics advancing seaward. Reflection coefficients are calculated in three ways. The first method is based on the normalized height of the reflected wave train as compared to the normalized height of the incident wave energy. The other two methods are energy methods, comparing the time-averaged reflected wave energy to the time-averaged incident wave energy, with one of the energy methods accounting for the difference between the still-water level and the mean water level at the toe.

An option in the program allows prediction of armor unit stability by calculating the variation of local stability number along the slope. The minimum computed value of the stability number corresponds to the critical stability number for initiation of armor movement. Calibration for armor stability and movement requires coefficients for shape, volume, lift, drag, and inertia of the armor units. Few data are currently available for these coefficients, but attempts are currently being made at CERC to develop tables of data for these parameters based on previous research. Use of the program for stability predictions therefore will not be covered in this paper; additional information on the numerical stability model may be found in the user manual for the program.

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[1]Kobayashi, N., and Poff, M.T. 1994. "Numerical model RBREAK2 for random waves on impermeable coastal structures and beaches," *Research Report No. CACR-94-12*, Center for Applied Coastal Research, Dept. Civil Engrg., Univ. of Delaware, Newark. 325 pp.

[2]Madsen, O.S., and White, S.M. 1976. "Energy dissipation on a rough slope," *J. Waterways, Harbors and Coastal Engineering Div.*, ASCE, 102 (WW1), pp. 31-48.

Although the program is limited to nonporous structures, the geometry is arbitrary and compound slopes, offshore bars, and attached berms are acceptable profiles.

Inputs: Inputs are stored in a data file which is requested at the beginning of the program. Primary inputs concern structure geometry, incident wave conditions, and roughness of the slope (friction coefficient), plus a set of values to specify the desired run options and computed data to save in files created by the program. Dimensional data for structure geometry and incident wave conditions may be entered in either metric or US customary units, with the system of measurement being specified in the primary input data file.

Structure geometry may be input either as a set of coordinate pairs designating the ends of linear segments of slope, or by length and angle of individual linear segments of structure cross section. If the program is to compute maximum runup, it is necessary that the slope extend far enough above the still-water level (swl) to prevent overtopping, and an error message will be returned if the slope is of insufficient length. Alternatively, the program has the option of calculating the overtopping rate for lower structure crests. Depth at the toe is also required as an input.

Spectral waves are represented by a time series stored in a separate file. The name of the time series file is listed in the primary input data file. The first line of the time series file gives the number of time-steps in the file in an I8 format, then the water surface elevations are given in a 5D13.6 format beginning on the second line. The frequency of water surface elevations in the time series is given in the primary input data file as number of data points per wave period.

Determination of friction coefficients: In order for RBREAK2 to be useful on armored slopes, the appropriate friction coefficients must be determined. Friction coefficients were determined by comparing predicted runup to a series of large-scale tests conducted in a wave flume using maximum zero-damage wave heights. Regression analysis was used to define the following relationship:

$$f_w = C_O \left[\frac{d_{n(50)}}{L_o}\right]^{C_1} (\tan\theta)^{C_2} \tag{1}$$

where f_w is the friction coefficient, $d_{n(50)}$ is the nominal diameter of the median armor stone (cubic root of stone volume), L_o is deepwater wavelength, $\tan\theta$ is tangent of the structure slope to the horizontal, and C_0 , C_1 , and C_2 are regression coefficients with the following values:

$$C_0 = 2.3508$$
$$C_1 = 0.5511$$
$$C_2 = 0.6145$$

Runup coefficients in RBREAK2 are determined by water surface elevation above the slope, that is, thickness of the film of water on the slope. Selection of different values for runup thickness will change the calculated runup elevation. Runup values used to determine Equation 1 were calculated with a runup thickness of about 3 percent of the average $d_{n(50)}$. For comparison, selected tests were rerun with the same friction coefficient but with the runup thickness reduced by half. The change in runup was less than 1 percent.

Use of numerical model: Before running RBREAK2, computer program BEFORR2 is run using the

same input files prepared for RBREAK2. BEFORR2 checks the contents of the primary input data file and returns error messages if the data do not meet the necessary criteria. BEFORR2 next checks the hydrodynamic computations for each computation unit (a computation unit is total length of time series divided by reference time period), and adjusts the computation parameters if necessary to avoid numerical problems in the analysis. Parameters adjusted by BEFORR2 are length of time-step used in the calculations and normalized water depth used to specify the computational waterline.

Output from BEFORR2 lists any problems encountered in the hydrodynamic computations and the adjustments in parameters made by BEFORR2 to overcome the numerical problems. BEFORR2 does not change the primary input data file, but creates a separate file that is read by RBREAK2.

ADDITIONAL INFORMATION*:* A complete description of RBREAK2, BEFORR2, a list of parameters, a computer listing, and examples may be found in Kobayashi and Poff (1994)[3] . Additional information may be obtained by contacting Mr. Donald L. Ward (601)-634-2092, Donald.L.Ward@erdc.usace.army.mil.

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[3]Op cit.